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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Snow in Natural Openings and Adjacent Ponderosa Pine Stands on the Beaver Creek Watersheds

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The Beaver Creek Watershed Project[3] was established to determine types of land treatments that would increase water yield in Arizona. Several pilot watersheds in the ponderosa pine (Pinus ponderosa Laws.) type are currently being calibrated. Annual precipitation on the watersheds is 24 inches, half of which comes during the period November 15-April 15. More than 99 percent of the annual runoff occurs during the same period, most of it originating from snowmelt. It is apparent from the role of snow in the runoff pattern that effects of overstory on snow accumulation and melt must be known to prescribe treatments to maximize water yield.

This exploratory study was designed to determine the relationship between snow accumulation and melt and overstory stocking conditions. There were no replications of the various stocking conditions. Factors such as slope and aspect were eliminated as much as possible to avoid confounding effects.

AREAS STUDIED

Snow accumulation and melt were studied in natural openings downwind from a timber edge, and in adjacent stands of ponderosa pine during the winter of 1963-64. The natural openings extended a minimum distance of 1,000 feet from the edge of the timber. The four areas selected for study represent existing levels of stocking and size-class distribution on the Beaver Creek Watersheds:

1. The ponderosa pine on this area was uneven aged with sapling, pole, and sawtimber size classes present. The basal area was 85 square feet per acre, and the average height of the dominant trees was 60 feet. This condition extended beyond 1,000 feet to the windward.

2. The timber here was a characteristic dense sapling and small pole stand common in southwestern ponderosa pine. The basal area was 65 square feet per acre, and the height of the stand was 20 feet. The stand was uniform 300 feet to the windward, beyond which was an uneven-aged pole and sawtimber stand.

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[3]A 275,000-acre watershed on the Coconino National Forest in northern Arizona where costs and benefits of intensive multiple-use land management are being evaluated as a part of the Arizona Watershed Program.

3. The ponderosa pine on this area was even-aged, large sawtimber with a basal area of 115 square feet per acre. The height of the timber was 100 feet. This stand extended for 400 feet upwind, beyond which was an uneven-aged pole and sawtimber stand.

4. The size classes represented here were similar to those found on area 1. The stand was dense, however, averaging 135 square feet of basal area per acre. The height of the dominant trees was 40 feet. The stand was uniform for 1,000 feet to the windward.

All of the areas were located with a northeast aspect where slope was less than 10 percent to minimize slope and aspect as variables:

	Average slope	
	Openings	Timber
	(Percent)	
Area 1	1	6
2	3	4
3	2	3
4	1	6

METHODS

Water-equivalent measurements were made on snow courses the day following each storm. Total snow was measured at each point; then, the "new" snow was removed and the "old" snow measured at the point. The interface between the "new" powder snow and the "old" snow was easily distinguished due to crust formation during the long periods and warm temperatures between storms. Additional measurements were made at 3- to 4-day intervals during the spring melt period.

Because major winter storms generally come from the southwest, the snow courses were located along a southwest-northeast line perpendicular to the edge of the natural openings. Each course began at the edge of the timber and extended northeast into the opening (fig. 1). The length of each course depended on the height of the timber adjacent to the openings. Snow samples were collected at distances of "H" (average height of adjacent timber): 0, 1/4, 1/2, 3/4, 1, 1-1/2, and 2 out into the openings. Additional samples were

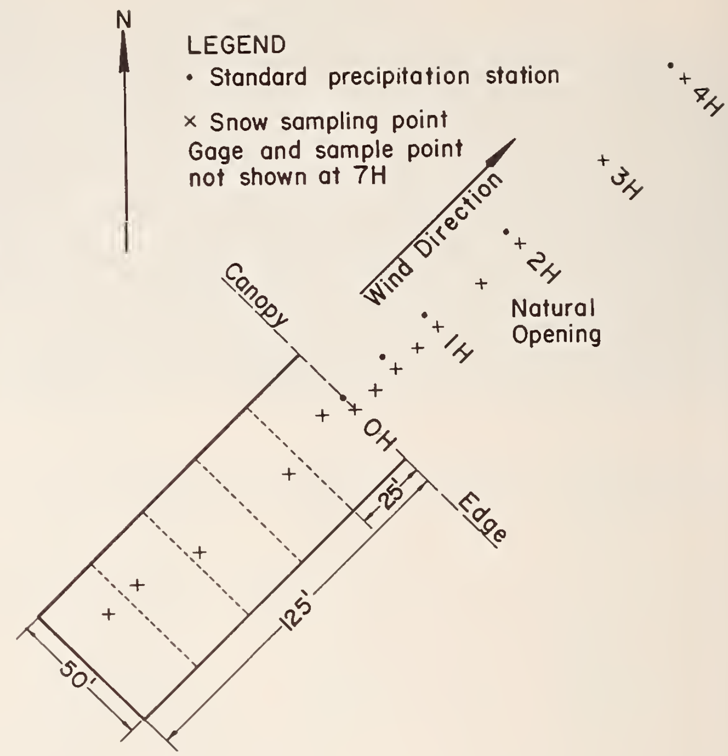

Figure 1.--Location of standard precipitation gages and snow sampling points in the natural opening and adjacent stand at area 4. Other areas were sampled similarly.

taken at 3, 4, and 7 H at area 4 to determine snow accumulation and melt at distances beyond 2 H.

Five sample points were selected in a plot 50 feet wide and 125 feet long in the timber adjacent to the opening to determine effect of overstory on snow accumulation and melt within the timber (fig. 1). Each plot was subdivided into five subplots of 50 by 25 feet, and one sample point was randomly located in each subplot. Basal area was determined at each sample point by point sampling with a basal area factor of 10.

RESULTS

Accumulation and Melt

Openings

Snow accumulation in the openings is shown in figure 2. In all cases the water equivalents at points out from the edge of the canopy were plotted in terms of tree height. The resulting accumulation profiles were quite similar regardless of stand condition, with the exception

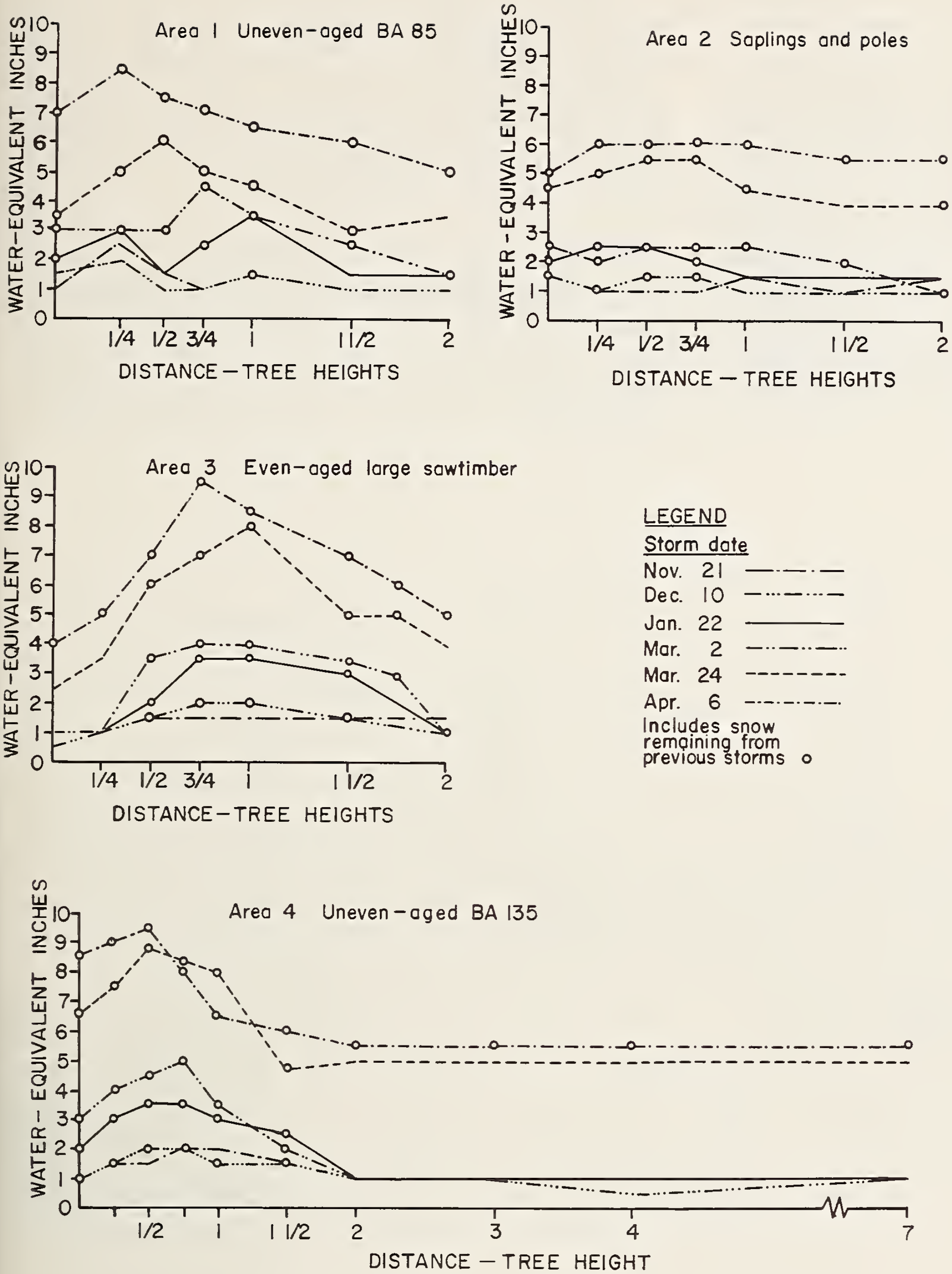

Figure 2.--Snow accumulation in the openings adjacent to four ponderosa pine stands.

of the opening adjacent to the sapling and pole stand, which accumulated somewhat less (fig. 2, area 2). The smaller catch in the sapling and pole stand was possibly influenced by the nearby taller stands.

Some snow was held through the winter in a "zone of retention" extending from the edge of the natural openings to a distance of 1-1/2 H to 2 H (see circled points in fig. 2). All snow beyond 2 H disappeared between successive storms without producing runoff, except for the last two storms when relatively large snowfalls occurred within a 2-week period. The "holding" of snow by the canopy resulted in an average of 2.0 inches of water in the snowpack on March 21 (6 days before start of runoff) at a point 1/2 H from the canopy. The average water equivalent of the snowpack from the canopy out to a distance of 1 H represented over 40 percent of the current winter precipitation. Lesser amounts remained out to 2 H with none remaining beyond 2 H. Although measurements were made be-

yond 2 H on only one area, it was observed that the other areas lost snow similarly.

Melt trends from April 7 to April 20 for the four areas are shown in figure 3. In general snow farthest from the canopy melted most rapidly. This resulted in the last snow lying in a narrow "zone of retention" directly adjacent to the canopy. An exception to this is the even-aged, large sawtimber stand (fig. 3, area 3). A "hole" in the canopy allowed the afternoon sun to shine on the snowpack adjacent to the canopy, thus depleting that portion of the snowpack more rapidly.

The melt data from the four areas were used to compute average daily melt rate at varying distances from the canopy. The resulting curve (fig. 4) shows that the canopy reduced melt rates out to 2 H. Directly adjacent to the canopy the melt rate was about half that of the unaffected areas.

In general, snow disappeared from the four openings at about the same time. An exception was the opening adjacent to the sapling and pole stand, where the snow left somewhat earlier due apparently to the smaller initial snowpack.

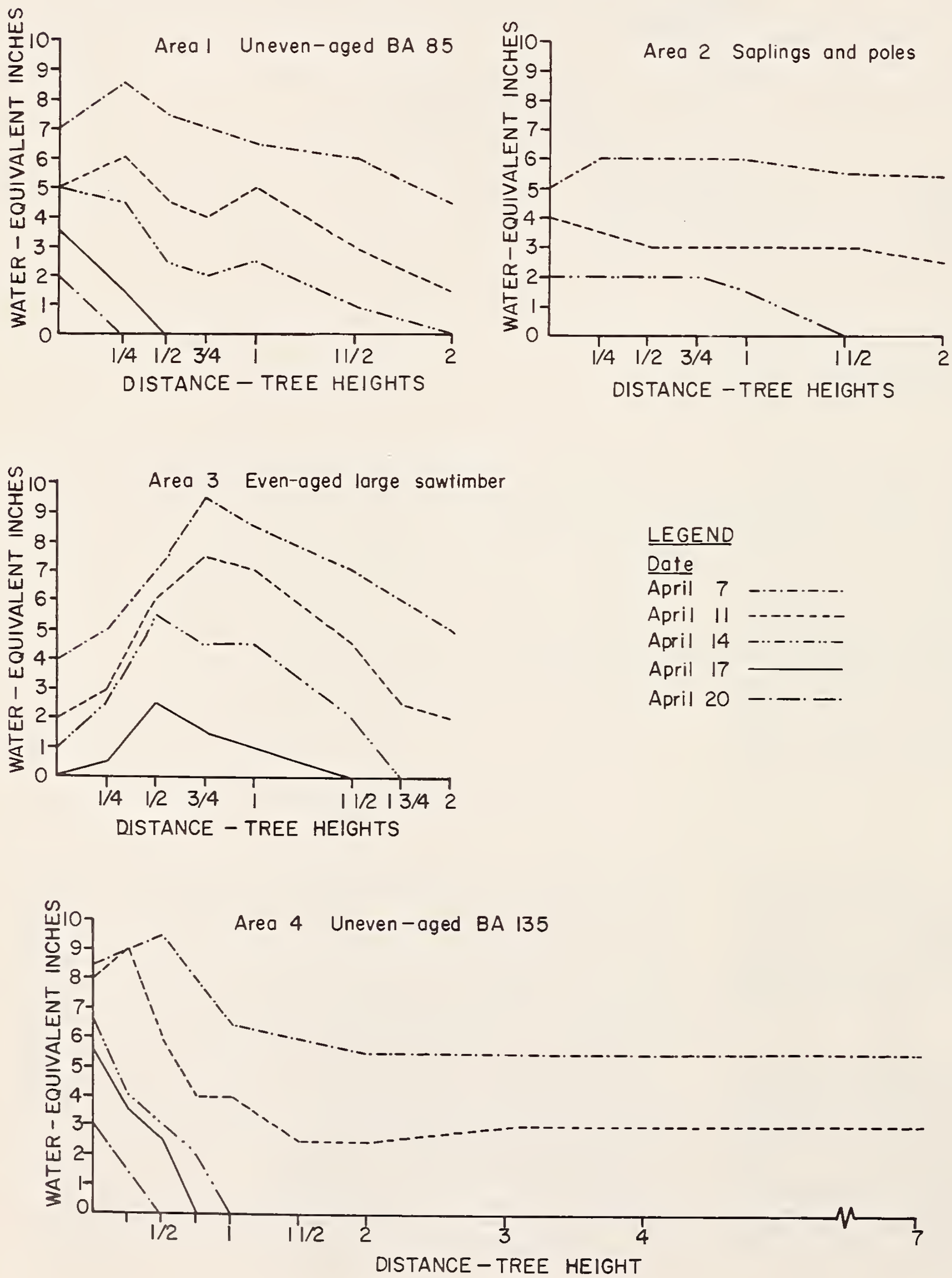

Figure 3.--Snowpack depletion in the openings adjacent to four ponderosa pine stands.

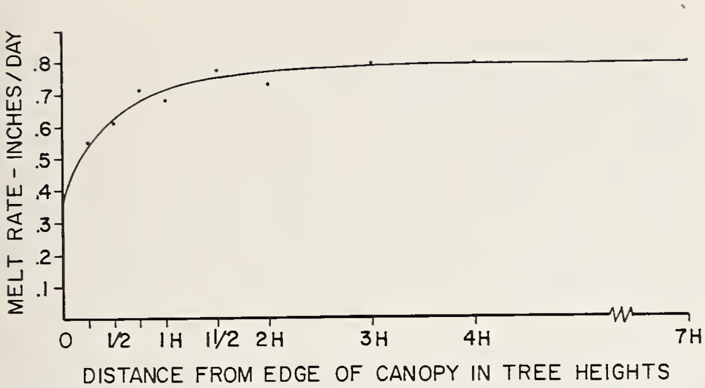

Figure 4.--Average melt rate of snowpack from April 7 to April 20 (inches per day).

Timber

The data obtained from four stands of timber are summarized in table 1. The water equivalent on March 21 shows the relative ability of the different stands to hold snow prior to spring runoff. March 21 was just prior to the last major snow storms of the season and start of spring runoff, so any snow remaining at that time contributed to runoff. Average water equivalent at the time of maximum accumulation, April 7, and subsequent melt in the timber are also shown. The amount of melt was computed for the period of major

Table 1.--Snow accumulation and melt in timber, and influence of various stand types

Size class and area number	Basal area	Water equivalent remaining March 21[1]	Accumulation, Apr. 7[2]	Melt, Apr. 7-14[3]	Influence of stand type on snow accumulation and melt
	Sq.ft.	- - Inches of water - -			
Saplings and poles (Area 2):	65	1.9	6.1	4.1	Held most water equivalent on Mar. 21; probably due to many small "holes" in canopy plus adequate shading provided by a canopy which was continuous down to the ground; maximum accumulation, greatest of all stands; melt measured during 7-day period similar to two other stands.
Uneven-aged (Area 1):	85	1.4	5.1	3.9	Canopy nearly continuous; water in snowpack on March 21 was 0.5 inch less than in sapling-pole stand; melt not significantly different from sapling-pole stand or uneven-aged stand of Area 4; maximum accumulation intermediate.
Uneven-aged (Area 4):	135	.6	5.6	3.3	Similar to Area 1 except stocking greater and canopy did not extend down to ground; water equivalent on March 21 was second smallest of areas studied; melt considerably less than other three areas, probably due in part to relatively high stocking level.
Even-aged, large sawtimber (Area 3):	115	.1	4.7	4.2	Characterized by large, scattered sawtimber; poorest in terms of water equivalent remaining March 21; smallest maximum accumulation; melt rate slightly higher, but probably not significantly different from Areas 1 and 2.

[1] Just prior to last major storms and start of spring runoff.
[2] Date of seasonal maximum accumulation.
[3] Period of major melt

melt, April 7 to April 14. The seasonal peak discharge on adjacent ponderosa pine watersheds on Beaver Creek occurred in the middle of this period (Apr. 11). The influence of the various stands on snow accumulation and melt is described in table 1.

PRECIPITATION DISTRIBUTION

In the opening at area 4, snowstorm precipitation was measured to the leeward of a forest edge by two methods: (1) with a snow tube and scales, and (2) with U.S. Weather Bureau standard precipitation gages (fig. 5). The standard precipitation gages were placed in a line perpendicular to the edge of the canopy and parallel to the prevailing southwest wind direction (see fig. 1). Distances from the 40-foot-high canopy, in terms of the average dominant tree height (H), were at 0 (edge of canopy), 1/2, 1, 2, 4, and 7 H. Snow sampling points, offset about 5 feet from the line to minimize influences from the precipitation gages, were at distances of 0, 1/4, 1/2, 3/4, 1, 1-1/2, 2, 3, 4, and 7 H.

Figure 5.--U. S. Weather Bureau precipitation gage at area 4.

The unshielded orifices of the gages were 48 inches above the ground. The gages were charged with an antifreeze solution to prevent freezing, and an oil film to reduce evaporation. The snow water equivalent was sampled with a snow tube (to 1/2 inch) and scales the day after each storm. At the same time the precipitation gages were weighed, which determined their catch to 0.04 inch.

There were six storms with totals of 1 inch or more of moisture during the winter: four of about 1 inch, the other two of 2-1/2 and 3-1/2 inches as measured in the standard precipitation gages (fig. 6). For each of these storms catch was reduced from the edge of the canopy to beyond 1/2 H. There was relatively little difference in catch from 1 H on, although in four of the six storms the amounts declined slightly as distance increased from the canopy.

It was not possible to compare the two methods of measurement for individual storms due to the minimum size of increment that could be measured with a snow tube (1/2 inch). The cumulative values for five storms did allow a comparison between the two methods, however. The sixth storm (Apr. 7, 1964), which was composed of mixed rain and snow, was discarded since it was not possible to determine with a snow tube the amount of moisture that fell at a point.

Precipitation as measured by the two methods was summed for the five storms for each point. Only new snow deposited by each storm was used in the summation. The resulting accumulation profiles are shown in figure 7.

From 3 to 7 H, all differences in measurements were attributed to sampling precision, but in the band from the edge of the canopy out to beyond 2 H, there was more precipitation deposited on the ground than was

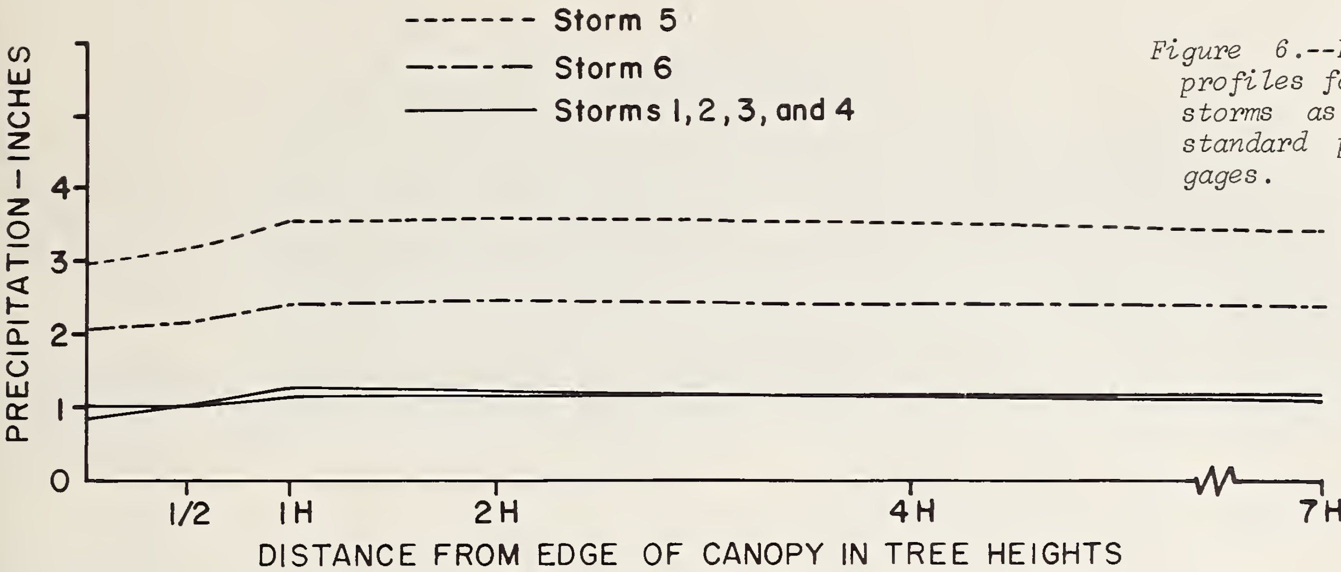

Figure 6.--Precipitation profiles for individual storms as measured in standard precipitation gages.

measured in the cans. The reason for this difference is not known, but it appears that it was not due to drifting of snow from farther out in the opening back toward the canopy. Such a situation would have resulted in snow-tube measurements substantially less than the amount measured in the standard gages at some point in the opening. In addition, temperatures during the storms were generally mild, and field observation showed little sign of drifting in the area.

The amount of snow intercepted by the canopy varied from nothing to apparently considerable amounts. This interception appeared to have no effect on the distribution of snow out from the canopy. It is possible that the amount of snow on the ground as measured with the snow tube is close to the true amount deposited at that point, and that increased turbulence and eddy currents associated with a canopy edge reduced catches in the standard gages.

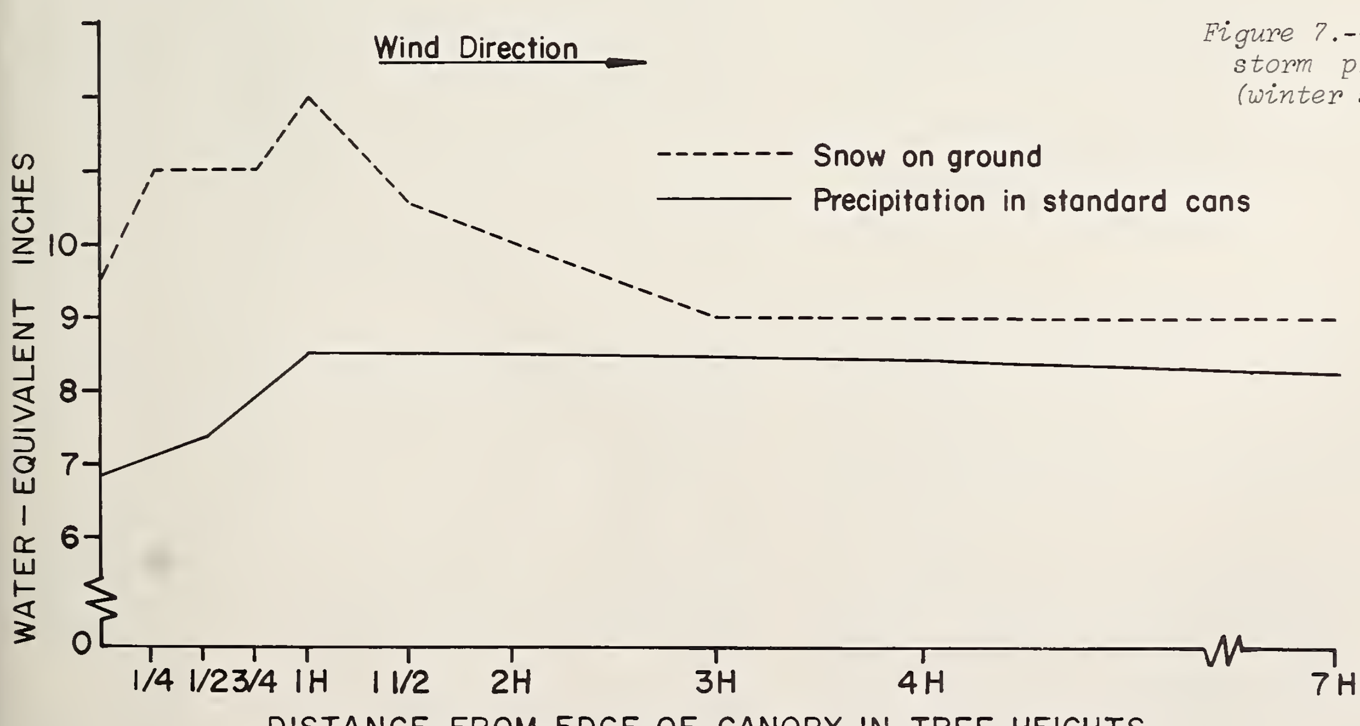

Figure 7.--Sum of snow storm precipitation (winter storms 1-5).

CONCLUSIONS

1. A sapling and pole stand held the most snow just prior to spring runoff, and had a relatively high melt rate in the spring. Such characteristics would be desirable for maximizing surface runoff in a short time period.

2. A small amount of snow held through the winter in an uneven-aged stand with basal area of 135 square feet melted slowly in the spring. This characteristic would be desirable for minimizing surface runoff and/or extending the timing of runoff.

3. An even-aged, large sawtimber stand held almost no snow throughout the winter, but had a fairly high spring melt rate.

4. An uneven-aged stand with a basal area of 85 square feet was intermediate in its influence on holding snow and melt rate.

5. Snow was held in a "zone of retention" in openings throughout the winter out to distances of 1-1/2 to 2 H, regardless of tree height or stocking conditions tested.

6. Forty percent of the winter precipitation that fell in a band 1 H wide adjacent to the canopy was held until just prior to the start of spring runoff.

7. All snow disappeared between successive winter storms at distances beyond 2 H with the exception of the last two storms, which occurred within a 2-week period and contained large amounts of snow.

8. There was more water equivalent in the snowpack from 0 to 3 H as measured by a snow tube than was caught in standard precipitation gages.

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